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STRATEGIES FOR DIGITAL TRANSFORMATION IN CONSTRUCTION PROJECTS: STAKEHOLDERS' PERCEPTIONS AND ACTOR DYNAMICS FOR INDUSTRY 4.0

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SUMMARY: *This study explores and presents the roadmap of industry 4.0 for the Indian construction industry with particular reference to project management practices. Accordingly, this study explores stakeholder dynamics for adopting digital technologies in the construction sector, especially those affecting construction project management. The study adopted one focus group with five participating panellists that provided the qualitative data. This is followed by a questionnaire survey with wider practitioners from the public and private sectors to validate the findings and rank the hypothesis to enable the implementation. Based on a focus group, this study proposes thirteen hypotheses describing stakeholders' dynamics. Furthermore, based on the questionnaire survey validation, this study finds that the top four strategies are stakeholder integration, process re-engineering, training activities, and the need to generate federated data. We interpret the journey of industry 4.0 in the construction industry as having its effect from at least four perception frames: redundancy, accommodation, amplification, and introduction. Practitioners can make process changes in their organisations while delivering projects using industry 4.0 in the construction sector. The findings are contextual to the Indian construction industry. While there is a richness of data that emanated from experienced practitioners, future case studies could enhance the applicability of the findings. The article takes a visionary stand to enable practical aspects of adopting industry 4.0 in its full measure.*

KEYWORDS: *Project-based organisations, digital transformation, stakeholders' perceptions, actor dynamics, construction 4.0.*

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1. INTRODUCTION

The history of project management presents ample examples of technological needs-driven management innovations on projects (Sankaran et al., 2021). Industry 4.0 is now well understood as a fundamental anchor for digital transformation. Industry 4.0, while radically addressing many challenges of the conventional delivery models and bringing manifold benefits in terms of productivity, cost, quality, time, resource efficiency, collaboration and communication, safety, and sustainability (Craveiro et al., 2019; Oesterreich and Teuteberg, 2016), has brought about a certain degree of ambiguity and lack of clarity, especially in its adoption and adaptation (Karmakar and Delhi, 2021; Muñoz-La Rivera et al., 2021; Winfield, 2020), even to an extent to say that we are not in a position to even understand the readiness of construction sector for industry 4.0 (Maskuriy et al., 2019). For instance, industry 4.0 in the construction sector has caused productivity gains when lean construction concepts based on integrated project delivery methods are coupled with building information modelling (BIM) based digital twin technologies. Nevertheless, the data transfer's reliability and interoperability impede and challenge the wider application (Karmakar and Delhi, 2021).

The digitalisation of project environments is perceived as a disruptive, inflective, and jolting phenomenon (Criado-Perez et al., 2022). The strategic imperative of digital transformation includes digital resources, organisational structures, growth strategy, and metrics and goals (Adekunle et al., 2021). However, the main criticism is that with a fragmented array of technologies that vary from the use of drones for site monitoring to the creation of sophisticated platforms and digital twins with embedded artificial intelligence (AI) and machine learning (ML) for megaproject planning and control, construction 4.0 continues to be a work in progress (Sherratt, 2020). Furthermore, a persistent gap observed among the past studies is the focus on adopting one or a few digital technologies but not the range of industry 4.0 tools. One reason is that a number of technologies have matured and are now accessible (e.g., BIM, Cloud Computing, Mobile Computing, Modularisation), and several technologies remain in their infancy while uses and models for general usage are being created (e.g. Additive Manufacturing, Augmented, Virtual and Mixed Reality) (Oesterreich and Teuteberg, 2016). Extant literature also pointed out technological challenges emanating from workflow, interactions of subsystems, uncertainty, trust, and employee attitudes (Schneider and Sting, 2020; Wagg et al., 2020).

Digital transformation and adoption hinge on several dimensions spanning organisational and stakeholder spaces. This is critical since research revealed that local stakeholders had varying views about localised digital solutions in projects (Wang and Lu, 2021). According to Alaimo & Kallinikos (2021), organisations can no longer be framed as separate from the technologies they deploy. Thus, there is a need to understand the dynamics of digital transformation with the organisational processes and project participants, especially in the construction industry. It is crucial to understand whether digital technologies impact project management approaches (will) and how they would impact (how). Thus, it became imperative to inquire about the 'will' and 'how' of the construction sector's journey on the industry 4.0 path.

A crucial aspect in this enquiry of 'will' and 'how' involves understanding the active involvement of project participants and exploring an organisational setup suiting the project situation. Hence, consistent with the actor, practise and strategy (APS) connections highlighted in Martinsuo et al. (2020), we argue that industry 4.0 would revolve around the interlinkage of technologies and humans. In particular, we argue that industry 4.0 success depends on the acceptance, change, and interactions of the technological processes between the constellation of actors and the strategies that govern them. For instance, actual project practices may not happen as per the formal project prescriptions, even from age-old bodies of knowledge that lays management principles and techniques (Pellegrinelli et al., 2007). Thus, the strategy would be the chord that binds the change at hand, i.e., adopting industry 4.0 tools, technologies and their process to the acceptance of diverse stakeholders such as owners, suppliers, technology providers, public governing agencies, vendors, builders, among others while coordinating the project activities and completing the goals of the project. This blurs the lines between planning and implementation, and projects would eventually become vehicles of change management (e.g. adoption of industry 4.0 in this context) (Martinsuo et al., 2020).

In this study, the objective is to understand the dynamics of the project participants in enabling the adoption of industry 4.0 in the construction sector in a holistic approach. As indicated earlier, the study looks at the 'will' and 'how' to understand the stated dynamics.

2. LITERATURE REVIEW

2.1 Construction 4.0

Industry 4.0, since its rise at the turn of the 21st Century, has penetrated many industry sectors. The ten usually stated dimensions of industry 4.0 are cyber-physical systems, internet of things, big data and analytics, cloud technology, artificial intelligence, blockchain, simulation and modelling, visualisation technology (augmented and virtual reality), automation and industrial robots, and additive manufacturing (Bai et al., 2020; Dalenogare et al., 2018; Karmakar and Delhi, 2021; Silvestri et al., 2020). These technologies, which may be divided into three categories based on the physical/automation domain, simulation and modelling, and digitalisation and virtualisation domain, have ongoing or future uses across the life cycle of a building project (Muñoz-La Rivera et al., 2021). Construction 4.0 is the engineering and construction industry's counterpart of the Fourth Industrial Revolution, in which the industry is becoming more digitalised. Industry 4.0 adoption has relied on tools like the BS EN ISO 19650 series, which is seen to have missing standards because of its unbiased and complete nature (Winfield, 2020).

Various researchers have examined industry 4.0 in the construction industry with diverse goals and objectives, finally pointing out that sync of various tools and technologies is needed for optimal benefit. Dallasega et al. (2018) take a proximity perspective of Industry 4.0. They present a framework for explaining Industry 4.0 concepts that increase or reduce proximity. Industry 4.0 technologies mainly influence technological, organisational, geographical and cognitive proximity dimensions. Maskuriy et al. (2019) mapped the state of Industry 4.0 in the construction industry to identify its key areas and evaluate and interpret the available evidence. They find that the extant literature has been argued to focus on three clusters: technology, security, and management. Sherratt (2020) highlighted workers and work features, particularly relating to ethical and social dimensions, are focussed by researchers of construction 4.0. Oesterreich and Teuteberg (2016) pointed out the political, economic, social, technological, environmental and legal implications of Industry 4.0 relating to technology adoption in the construction industry. Jayashree et al. (2022) showed that the effect of IT resources (the technology context), management leadership, teamwork (the organisational context), and external support (environmental context) is significant in Industry 4.0 adoption. Dalenogare et al. (2018) noted that some emerging technologies might not impact the project performance in isolation, but actual value can only be harnessed with synchronous orchestration of the various tools and technologies. Industry 4.0 adoption is relatively low in developing countries, while the developed countries have adopted it reasonably well, led by Germany. While many studies can be reviewed on industry 4.0, this section focuses only on industry 4.0 as relevant to the construction industry.

2.2 Digital transformation

The term "digitalisation" refers to the use of various digital technologies and web-based services that allow for the storage, transfer, and exchange of large amounts of data, along with aiding, substituting, or collaborating with humans at work (Hallin et al., 2022). In this regard, digital transformation is viewed "…as a malleable form of organising that enables continuous adaptation for influential digital ecosystem orchestration (Ivarsson, 2022: 6374)." A few decades ago, adoption was perceived by metrics such as technology adoption curves, among others. Now, in the digital transformation journey of a sector or industry, three distinctions are essential in understanding the system. Implementation and diffusion are combined into one idea called adoption (Kassem and Succar, 2017). The idea of diffusion describes how a system or method spreads throughout an adoptive population. Implementation is the group of steps taken to set up, use, or enhance a specific output and the associated processes (Kassem and Succar, 2017).

Extant literature discussed disruptions from many perspectives. They include technical disruptions, such as changes due to a new technical intervention (e.g. a new ERP system or system integration), social , such as strikes and political events, abnormal events, such as crises, including the distinction of crises as an event and crisis as a process (Silva and Fulk, 2012; Unterhitzenberger et al., 2021; Williams et al., 2017). A few studies discussed the project-level challenges during disruption. The effects include shortage of manpower, shortage of resources, changes of techniques or production, changes in the disciple that affect the organisational efficiency, resistance from users such as failing to do their jobs, avoiding to use of the new intervention, damaging property belonging to their employer, failing to provide those implementing the ERP system with helpful information, or threatening to resign from their positions (Silva and Fulk, 2012). Communication problems in project teams are one of the challenges in times of disruption (Bayhan et al., 2022). The disruptions result in the disposition not to cooperate, contradicting interpretations, lack of fit, and increased workload. Similarly, projects would experience time overrun, cost overrun, negative social impact, idling of resources, and disputes emerge in case of disruption (Arashpour et al., 2014). This is because disruption reduces labour productivity and causes exponential increases in project duration (Lishner and Shtub, 2021). Disruption also costs extra learning, altering or delaying the usual learning curve in the project personnel (Eden et al., 1998). On the whole, the disruption can lead to interruptions to planned tasks, even to the extent that the project fails (Rahi, 2019). Thus the awareness of disruptive events and the budgeting of resources play a crucial role in project resilience (Rahi, 2019).

Based on a bibliometrics review, Adenkule et al. (2021) proposed a balanced flow model for DT discussion in the construction industry. This has external drivers of digital transformation, phases of digital transformation, and strategic imperative of digital transformation. Criado-Perez et al. (2022) offered six provocations highlighting major challenges for the AEC industry in digital transformation. They note that several field-level obstacles to innovative strategy characterise the AEC sector. In the face of new difficulties, the dispersed AEC sector is ill-equipped for strategic collective action. In AEC businesses, strategic thinking about business models and how digital transformation may dramatically alter business models is typically in its infancy. The majority of the time, rather than being driven deliberately, investments in a digital transformation are reactive and fragmented. AEC companies are stifling successful collaboration by failing to embrace a coordinated and consistent approach to digital technologies. There are critical knowledge and skill gaps in the industry that prevent it from fully realising the advantages of a digital revolution. Technological evolution necessitates ethical decisions by project directors about how to incorporate innovation into projects, merging generations of technologies created across diverse timelines (Whyte et al., 2022). Inconsistencies and incongruences among the various actors badly affect the digitalisation outcomes (Lundberg et al., 2021).

Some attempts were made to bridge the gap in understanding the path of digital transformation. Accordingly to Jones (2021), digital transformation and industry 4.0 fundamentally require technological and cultural change. Also, digital technologies introduce four kinds of human-technology relationships into construction processes (Voordijk, 2019). The first is a hermeneutical relationship in which digital technologies contain data in a certain form that demands interpretation to offer any insight into those facts. The second is a background relationship in which digital technologies contribute to form the setting in which experiences occur but play no major role in their interpretation. The third type of relationship is one of alterity, wherein digital technology serves as a "quasi-other" to whom users relate. The final type of human-technology relationship is an embodiment in which technologies are perceived as normal extenders of the body and incorporated into normal activities (Voordijk, 2019). When an actor champions digital transformation, three emergent visions for the sector's digital transformation can be seen. These visions are efficient construction, user-data-driven built environment, and value-driven computational design (Ernstsen et al., 2021). Criado-Perez et al. (2022) propose a framework consisting of four leadership thinking schemas to enable digital transformation readiness: future thinking, strategic thinking, capability thinking, and experimental thinking.

Organisational change literature yet only partially explained the digital transformation processes (Hanelt et al., 2021). In a spectrum of a weak focus and narrow scope to a strong focus and broad scope, digital transformation can be just a technology impact or a systemic shift, a compartmentalised adaptation, and finally a holistic co-evolution. This holistic co-evolution addresses practical questions, such as how firms can achieve change and stay relevant in a rapidly changing digital environment (Hanelt et al., 2021).

2.3 Stakeholders' perception

The stakeholders in the digitalisation journey are diverse. These include but not limited to employees of various organisations or the project staff, the public and private sector organisations, BIM technology providers, and BIM consultants, among others. Some employees would need to embark on the change and alteration of practices. Some organisations would need to strategise the change. There are BIM technology providers, consultants and BIM champions that anchor and progress the change. Some government agencies want to reap the benefits of digitalisation in their public infrastructure delivery. Against this backdrop, it is essential to highlight that the infrastructure development agenda has been coupled with the digitalisation objectives of some of the significant infrastructure delivery programmes across the globe. For instance, the UK mandates BIM for all major public infrastructure projects. The ability and capability to deliver public infrastructure are challenged mainly due to the limitation of public sector competencies (Devkar et al., 2013; Manu et al., 2019). This capability can be viewed from individual, organisational, and national level competencies. The construction industry is one of the industries or sectors attributed to the least adoption of industry 4.0 technologies, while IT and technology and telecommunication lead the digital maturity in terms of adoption (Kane et al., 2015). On the other hand, Papadonikolaki et al. (2022) reviewed the frequency of digital innovations across data and found that BIM is the most adopted digital innovation. Even in systematic literature reviews of papers on construction 4.0, BIM has drawn much attention in practical publications (Oesterreich and Teuteberg, 2016).

2.4 Studies on individual technologies

Several studies focused on adopting specific industry 4.0 technologies in the construction industry from either an implementation perspective or the impact on project management. For example, Lu et al. (2022) studied blockchain adoption in projects. Holzmann et al. (2022) studied the use of artificial intelligence. Similarly, Voordijk (2019) examined radio frequency identification (RFID) to establish the human-technology relationship. Badi et al. (2021) studied smart contracts from the perspective of the technology-organisation-environment model. Bilal et al. (2016) remarked that the use of big data, which includes big data engineering and big data analytics, is relatively scarce in the construction sector and identified big data usage difficulties. Atuahene et al. (2020), extending the focus on big data, found that big data implementation requires developing expertise through organisational structures such as providing big data technologies, data management strategies and training, and a personal drive to learn. Similarly, Dallasega et al. (2018) systematically reviewed the supply chain management literature and found that the adoption of industry 4.0 is due to enabling the proximity for technological, organisational, geographical, and cognitive knowledge transfer, innovation, and inter-organisational cooperation. Elghaish et al. (2021) highlighted the many benefits of using drones in tandem with building information modelling, such as remote progress monitoring of construction projects.

Among the industry 4.0 related tools and technologies, most of the studies and use cases focused on BIM implementation (Heaton et al., 2019; Papadonikolaki et al., 2022; Wen et al., 2021). Furthermore, many studies focus on BIM adoption in diverse contexts (Hajj et al., 2021; Murguia et al., 2021; Papadonikolaki, 2017). With building information modelling (BIM) as the core of the cyber-physical system, the cyber-planning-physical system can accommodate BIM functionalities to improve the construction lifecycle (Maskuriy et al., 2019). This collaboration and autonomous synchronisation system can automate the design and construction processes and improve the ability to handle substantial amounts of heterogeneity-laden data.

However, since industry 4.0 has a constellation of diverse technologies (Pellegrinelli et al., 2007), a holistic approach to understanding the effects on the construction industry (Karmakar and Delhi, 2021) is presently missing. Further, the 'will' and 'how' questions remain largely unanswered, especially from the dynamics of adaption of the plethora of digital technologies from stakeholders' perspectives. Accordingly, this study addresses this gap by focusing on the dynamics of adopting various technologies with the processes and stakeholders in a construction project setup.

3. RESEARCH METHODOLOGY AND THEORETICAL FRAMEWORK

This study adopted a multi-stage mixed methodology - mixing methods at the empirical and conceptual levels. This is derived from Campbell and Fiske's (Campbell and Fiske, 1959) triangulation which refers to the use of quantitative research to corroborate qualitative research findings (Knight and Ruddock, 2008). The overall research methodology and framework are shown in FIG. *1*.

3.1 Focus group

One Focus group was carried out with Indian industry partners from the project management domain to simulate group discussion (Lazar et al., 2017). Based on the recommendation by Krueger & Casey (2014) regarding the number of participants, five expert members participated in the discussion in real time. Purposive sampling was adopted to ensure both the quality of data collected and a good mix of different stakeholders (See Table 1). Participants were only eligible if they had experience in industry 4.0 technologies and digitalisation for construction projects. The experience and credentials are shown in Table 1. Here, the experience in years is the expert's total experience in the construction industry as a practitioner. Author(s) facilitated the focus group discussion with a series of questions with opinion feedback wherein each expert responded in a sequence.

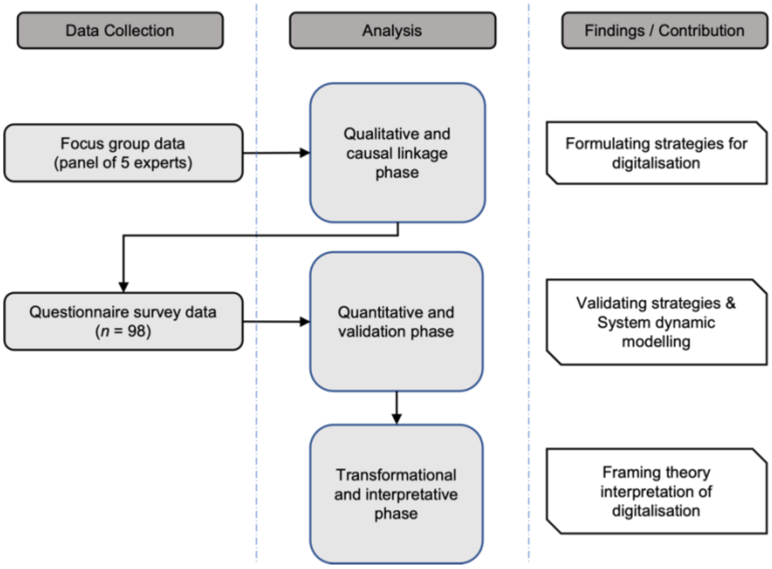

FIG. 1: Research framework of the present study

The experts also quantified their perception of each question on a 7-point Likert scale. The Likert scale (Likert, 1932), a form of a summative rating scale, is frequently used in psychology to measure attitudes. Likert scale construction is relatively simple. Each issue offers the respondents with usually five possible answers or seven, often on a spectrum of agree-disagree or approve-disapprove. Respondent indicates the degree of agreement and disagreement with a variety of statements about some concept that is subjected to testing. Two critical choices in the design of the Likert scale are whether to have an odd or even number of response options and then the length of the scale. The 7-point Likert scale is considered psychometrically optimal both in terms of rating and distinguishing the difference when consolidating the results with descriptive statistics such as measures of central tendency (Lozano et al., 2008; Preston and Colman, 2000). Furthermore, it is customary that focus group responses are quantified using various symbols by the researchers (see Leung et al., 2014). Similarly, in this study, the experts are asked to quantify their answers on a seven-point Likert scale, to remove any possible subjectivity of the data's moderator/researcher/coder. Care is warranted here as the purpose of the mean is not for statistical analysis based generalisability of findings which is also an advantage of using a focus group but using it as a process of collective sensemaking in a group with a set objective (Wilkinson, 1998).

The entire meeting lasted for 2 hours and 15 min. The meeting is recorded with the consent of the experts, transcribed verbatim, and analysed with Nvivo 1.2. Table 2 shows the statement form of each question to which panel members responded, along with the mean of the Likert scale ratings.

Table 1 Focus group expert details

Code	Exp. Yrs[&]	Summary of experience	Industry
Expert 1	15	Expert serves as vice president of the digitalisation and strategy wing of a leading unlisted company incorporated in pre-independent India. Expert is responsible for overseeing all the digitalisation initiatives across all the verticals of this EPC (Engineering Procurement and Construction) company. The company has over ₹ 500 crores in operating revenue as of FY 2020.	Private Sector
Expert 2	25	Expert represents the public sector. Expert heads the wing concerned about public road infrastructure projects, particularly highway projects with the state.	Public Sector (State)
Expert 3	40	Expert has worked for four major EPC firms and is now an independent digitisation consultant and the founder of a private digitalisation think tank to accelerate the digitalisation of the Indian construction sector.	Private Sector
Expert 4	14	Expert is both an academician and a practitioner as expert chairs the engineering department of his university. The expert also acted as a	Academician & Practitioner

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Code	Exp. Yrs&	Summary of experience	Industry
		digitalisation champion in their organisation's project. Expert has vast experience in terms of teaching and research in digitalisation	
Expert 5	12	Expert heads the execution of public infrastructure projects in the financial capital of India. Expert oversees the approval, monitoring, and payments of urban infrastructure projects with the power to grant projects or bills of value less than ₹ 1 crore.	Public sector (Urban development)

& total experience in the construction industry as a practitioner.

3.2 System dynamics modelling

System dynamics (SD) modelling has been utilised in project management research since it takes a complete approach and analyses the system's intricate and non-linear aspects (Rodrigues and Bowers, 1996). This method also aids in detecting the system's complicated condition and identifying the most effective intervention areas (Gillespie et al., 2004). SD is noteworthy for its capacity to propose an analytic solution for the system's complex feedback process, resulting in several uses, particularly in various aspects of project management (Park et al., 2009). SD is ideal for modelling inter-relationships such as non-linear behaviour, time-delay effects, and causal feedback for a complex system over time, i.e., knowing how one variable interacts with another variable over time using feedback and causal loop diagrams (CLD) (Boateng et al., 2012). CLD represents system dynamics through a conceptual structure derived from the modeller's understanding of the system (Park et al., 2004).

Causal loop diagramming was carried out to determine the causes and consequences of the strategies revealed in the focus group using Vensim PLE 9.2.1. For example, when expert 1 stated the following, *"[…] if the new process is not superseding the existing process. So, many times what happens is you want a new process also and the underlying old process as well and hence. The project team would not see many benefits in implementing it now. Hence there is a lot of resistance there so […]."* We established this relation in NVivo and a cause-and-effect link in the SD model between the code 'adding new processes to the existing process' to 'resistance'. Along similar lines, when expert two noted, "[…] *people say that they don't want such change […] and in that case, the top management must play a crucial role. In my case, the same thing has happened*." In the modelling, the polarity is determined by whether the strategy is favourably impacted (+ sign) or negatively influenced by another strategy or a system deficiency (- sign). The arrows reflect the interactions of several elements. The developed CLD model is shown in FIG. *3* (results section).

3.3 Framing theory as Theoretical Lens

The current study used the framing theory to understand technological advancements' influence. The framing theory was developed in psychology and is now widely utilised in social sciences to better explain the social development of collective action frames. Framing is about how people determine their actions. A frame is a scheme of interpretation in which the particulars of the events and activities we attend are organised and made sensible (Goffman, 1986). The fundamental proposition is that the interpretation frames generate the actions. Framing applies to situations, attributes, choices, actions, issues, responsibilities and news (Hallahan, 1999). The application of framing can be seen in organisational studies pertinent to strategy (Kaplan, 2008), change management (Schneider and Sting, 2020), technology (Kaplan, 2008), and policy studies (Schon and Rein, 1994), among others. In this study, framing theory is applied to understand the framing of the digitalisation journey among stakeholders so that the actions can be better analytically understood.

3.4 Questionnaire survey

Thirteen digitalisation implementation strategies from the expert focus group are subjected to validation using a questionnaire survey. The hypotheses from the focused group were formulated and tested with construction industry practitioners by collecting responses using an online survey. It is conducted over three months. After screening out incomplete responses, 63 valid responses were considered for analysis. Since nearly 150 questionnaires were sent, this study has a 42% response rate. The demographic profile is shown in FIG. *2*. The sample has respondents from the cross sections of the organisational levels, and as Figure 2 shows, 47.5 % of the respondents are from middle and top management levels, indicating a rich sample for validation.

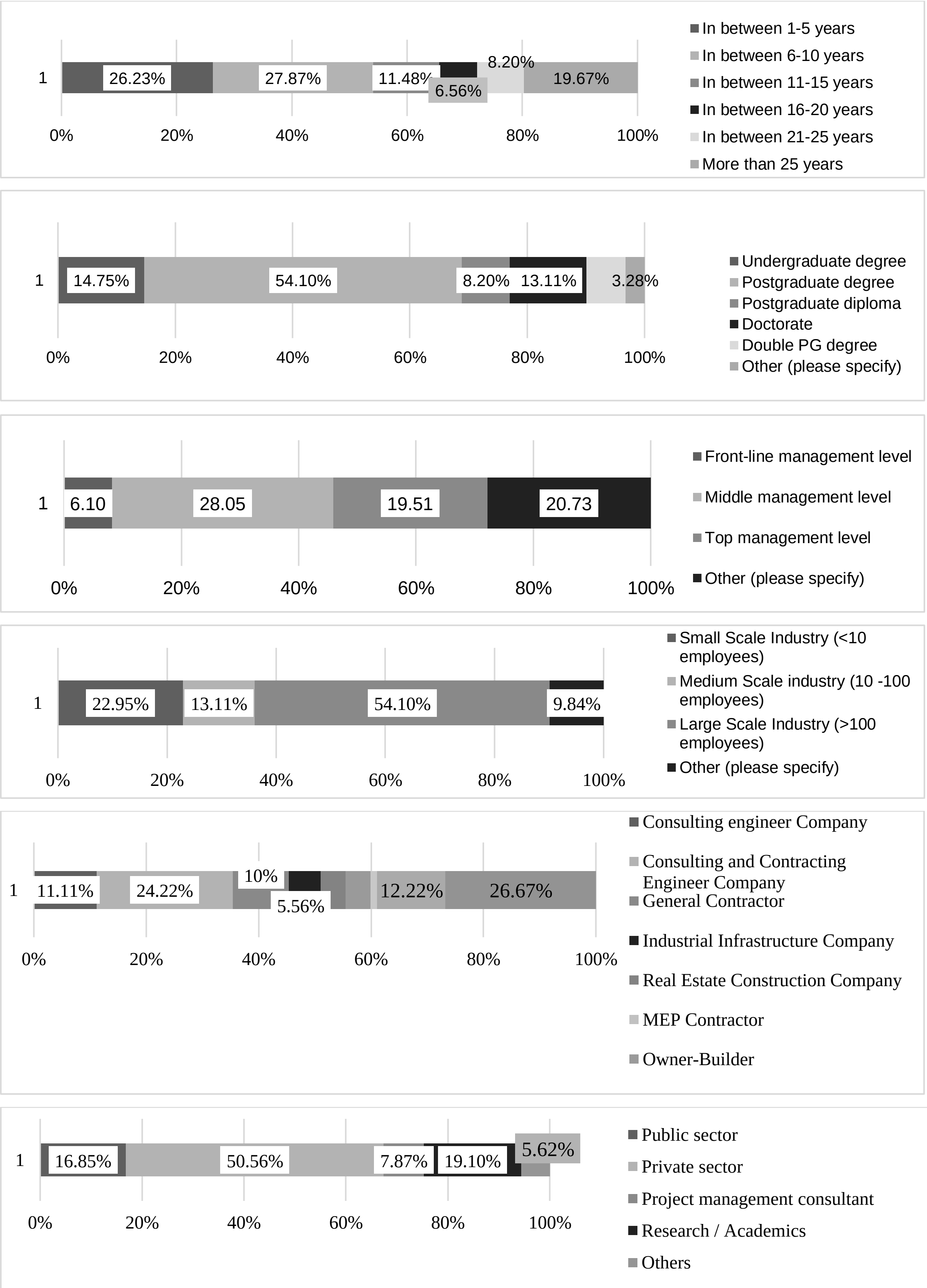

FIG. 2: Demographic Profile of the Respondents

The qualitative data gave idiographic findings, and the quantitative data gave nomothetic findings. Qualitative data gave the emergent or developmental perspective of the relationship between theory and concepts. In contrast, quantitative data helped with testing or confirmation.

3.5 Analysis of Questionnaire survey data

The validation is carried out using the relative importance index (RII), Mann-Whitney U (MWU) test for understanding the effects of PM certifications, and Kruskal-Wallis (KW)Test for understanding the effect of size of the industry, trade group and stakeholder group on the industry perceptions.

When the data does not follow any distribution, non-parametric methods will be used. The non-parametric Mann-Whitney U Test is employed to study the association of ordinal (rank order) data in a hypothesis testing situation with two independent sample groups based on their differences in ranks using SPSS 20.0 (Kraska-Miller, 2013). According to the Mann-Whitney test, the two groups are statistically different if the p-value is equal to or smaller than a predetermined significance level (α=0.05). On the other hand, there is no significant difference between the two groups if p is larger than this significance level (α=0.05). The respondents are primarily classified into two groups: ' having project management (PM) certifications' and 'not having PM certifications.

Next, Kruskal–Wallis test is a method that is used to check whether samples have emanated from the same distribution between two or more independent samples (Field A., 2005) by testing for any statistically significant differences. This is done to assess whether there is an agreement between various groups. The size of the industry, trade classification, and stakeholder classification is used for grouping, and then Kruskal-Wallis one-way analysis of variance is performed. The statistical hypothesis "*whether the distribution of the perception of strategy is the same across the different categories of grouping*?" has been tested. The results and interpretation are shown in Table 4 and discussed in Section 5.

4. FOCUS GROUP FINDINGS

The findings show that construction 4.0 affects project management's conventional principles to a limited extent but requires significant changes in the practices (see Question 1 and Question 2 in Table 2).

Table 2 Focus groups summary of mean

Q	Question translated to statement	FG1 Mean[&]
1	The practice of project management principles is getting impacted by digitalisation	5.14
2	Emerging digital technologies, such as AI, blockchain, cloud computing, and data science, alter/influence traditional project management principles.	2.94
3	Digitalisation impacts stakeholder management [Stakeholders – client, vendors, sub-contractors, affected communities, labour, etc., in a construction project.]	5.01
4	Implementing digitalisation in the project management process through	
	– Separate organisational structure	2.74
	– Modifying existing structures/roles	2.89
	– Inducting the chief development officer/ hiring someone as a change agent/process champion	5.45
5	Project staff positively responded to the digitalisation intended by the firm or client organisation	2.91
6	Change the implementation plan for all stakeholders	
	– Teams' formation	5.14
	– Communications	5.38
	– Training activities	6.74
	– Redefining the roles	5.21

[&] mean is for rating by the experts on a 7-point Likert scale.

All the experts termed the influence of industry 4.0 on the principles and practices of project management in the construction industry as disruptive (e.g., expert 2). The experts highlighted the benefits of industry 4.0 to the construction industry: data-driven execution, objective clearances, building intelligence through predictive analytics and strategic decisions, and, lastly, becoming an organised sector.

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For instance, expert three noted

> *there it goes with a few subjectivities, and that subjectivity is whether I was talking about AI-based inspection or AI-based remote approvals etc. or as EXPERT 1 was mentioning, and we have also thought of the blockchain-based contract management with all these subcontractors immediately, this execution is done, or probably the engineering is done, or any installation is done. A picture is uploaded, and then it can be verified on the AI-based tool itself, and the contract can be cleared for the next level, whether it is going for his bill approval or approval for that documentation or whatever it is. So that there is no touch of humans, and it goes automatically.*

The experts highlighted various strategies are needed to support the digitalisation of the construction industry. At a broader level, the strategies can be seen as orchestration-related, people-related, process-related, and data related. This emphasis can fit into an industry-driven strategy as opposed to a government-driven. Table 3 summarises the codes and themes that were extracted from the focused group. The corresponding system dynamics model of implementation strategies with balancing loops is shown in FIG. *3*.

Table 3: Codes and frequencies in the focus group data

Expert	**Implementation issues (all)**	**1. People related**	**2. Process related**	**3. Data related**	**4. Orchestration related**
1	12	1	2	1	9
2	15	6	1	1	7
3	14	5	1	0	9
4	7	2	2	0	3
5	18	7	4	4	7
SUM Total	66	21	10	6	35

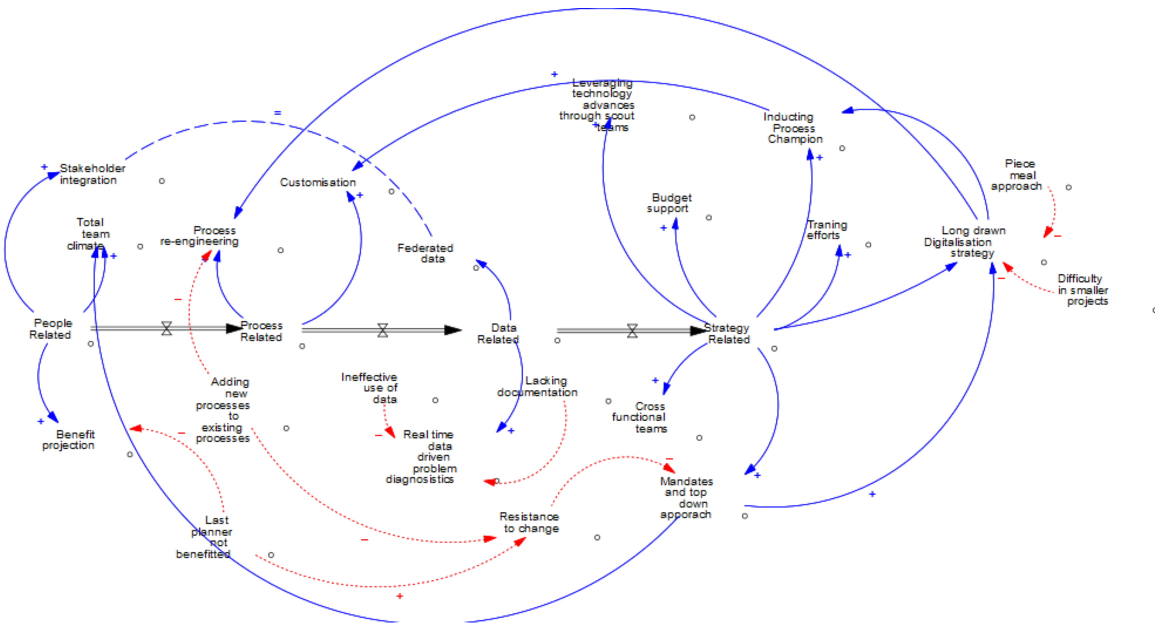

FIG. 3: System dynamics model of implementation strategies with balancing loops

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4.1 Orchestration related implementation

4.1.1 Hypothesis 1 (H1) Long drawn Digitalisation strategy

Digitalisation strategies are at the core of adopting industry 4.0 in the construction industry. This digitalisation strategy is argued to be long-drawn, involve every stakeholder group, and be complete and holistic in terms of its focus. The experts also argued that a strategy with a partial focus would not result in successful projects. In this regard, Expert three stated,

> *[…] unless the digitalisation happens, the fruit, or the result of the digitisation, which is happening or going on for quite some time, and it is very, very well, Uh, happening in bits and pieces.*

Similarly, expert one notes,

> *[…] within that any organisation, it is very much possible, but the strategy long-term strategy is required to be made. It is not a short-term strategy that you have thought of some implementing digital technology and data on this one and then just implementing it. It is going to bounce. It has to be a long ground strategy*

The strategy is suggested to incorporate the necessary organisational changes to support digitalisation. Expert 3 further elaborated,

> *[…] this is going to transform the entire company entire organisation, and that is, the structure must be changed. There could be many requirements for upscaling, re-scaling, and organisation changes, but that's a long-term strategy that needs to be taken and that's required.*

Thus, it is argued that only a long-drawn strategy would pave the way for either developing capabilities or inducting external change agents. Furthermore, the data suggest that the digitalisation strategy must be translated into a staged implementation plan. In this regard, expert one noted as follows.

> *[…] I will give you an example of robotics where what we have done is we have had at least four iterations of product development, product deployment and lessons learned from the project and again modifying the product. Now, if you look at the first product and the fourth product, what we have now is, I will say, 80% different. So, whatever the first product designed completely changed throughout last, I would say two and a half years, three years rather, so those are the kinds of strategic plans where we probably work with our partners together and have much longer gestation cycles of implementation.*

The experts suggested that besides having a long-drawn digitalisation strategy and staged implementation plans, there needs to be a budgetary provision in the strategy so that digitalisation can be effective.

> *An external change as well. Which must come up with some kind of a budget. If there is no budget, what happens? The external stimuli are change is kind of a burden to the organisation or the contractors dealing with this because they feel that this is not buried in the budget.*

Based on the focus group data, the first perceived hypothesis was

> *H1: Industry 4.0 needs to have a long-drawn digitalisation strategy*

4.1.2 H2 Mandates and top-down approach

Experts suggested that digitalisation has encountered challenges due to resistance to change. Data suggests at least three reasons: the project members are not aware of the technologies, they do not realise the benefit of the processes they execute, or the team members would want their activities not to be visible. Other stakeholder groups that need to change in this process are subcontractors and vendors. These stakeholder groups resist change unless the client takes a proactive approach and initiates to implement on a large scale.

In this regard, expert two from the public sector said

> *"…whenever the client makes the system mandatory, then it becomes for the vendor, subcontractor*

To solve this situation, the experts opined that the client's willingness is crucial in the digital transformation journey for all the stakeholders. They also asserted that clients would also affect the rate of digitalisation. This is reflected in the statement by expert three, which is

> *And if we want to implement it on a large scale, if a client takes it proactively, and if we make all these systems mandatorily, then we can get excellent results quickly.*

Similarly, expert five put it as

> *the timeframe will depend upon how the client takes these activities*

Overall, experts opined that mandates and a top-down approach are required for industry 4.0 to penetrate the construction industry. Based on the focus group data, the second perceived hypothesis was

> *H2: Industry 4.0 requires mandates and a top-down approach*

4.1.3 H3 Scout teams and external collaborations

Digitalisation also requires continuous upgrades for which strategic leverage has to be made. In this regard, expert one noted as

> *So, from a structural perspective, we have always believed in having a team which would continuously keep on scouting for new technology and see how it can be aligned with our current challenges or probably our future goals….*

However, the expert also mooted that implementable and impactful technologies would find a place at the organisation level. Implementable includes mapping the sophistication of the technology with the organisational teams. This would also mean having external collaborations to assist implementation. Based on the focus group data, the third hypothesis developed was

> *H3: Industry 4.0 adoption hinges on technology scout teams and external collaborations*

4.1.4 H4 Cross-functional teams

The adoption of industry 4.0 in the construction industry is argued to have teams at the centre. It requires cross-functional teams to break the silos of different wings of the organisation. This is argued to be needed to ensure the successful implementation of any technology. Accordingly, it is also argued that due to the incorporation of cross-functional teams, the existing organisation structure has to refine the rules and roles to allow the pursuit. In this regard, expert four stated that

> *I don't say that a separate organisational structure will be made. Existing organisational structure would be there. But definitely, it demands some modification.*

The experts also emphasised training the existing teams instead of hiring a team of technology experts. In this regard, expert one noted

> *we thought it was more beneficial to train our existing team. Let's say the planning team, costing Team, QS team, and design team utilise the model, and that's what the philosophy has helped. Similarly, in any other technology which we have implemented, we've always believed that. Technologies stay for ten years, and then something new comes up. What remains static would be our teams.*

Based on the focus group data, the fourth hypothesis developed was

> *H4: Industry 4.0 requires developing cross-functional teams*

4.1.5 H5 Process champion

The focus group interview findings reveal that process champions are required to support the adoption in cases where the existing organisational setup lacks the ability or will. The primary function of this champion is to balance the organisational dynamics and disturbances caused by newer technologies and set key performance indicators (KPIs) to ensure that the strategic change is reviewed and appropriate modifications are carried out.

In this regard, expert four noted,

> *So, internal change will work only when the champion will balance the organisational dynamics or disturbance, which happens in the system with the introduction of digitalisation. For example, if I appoint a, say, BIM manager. How is the BIM manager role, which was not there in the project setup or whatever it is, where in the hierarchy going to be placed, and how will he be mediating between the different roles in that organisational working practice or culture? All those things matter a lot because when a digital intervention happens, the guy who comes up with this knowledge will show his superiority over the other organisational fellows, decision makers, or whomever it is - that used to be there. That creates little disturbances.*

Similarly, expert five also reflected upon creating a post for championing the transformation in the public section organisation as

> *And in addition to these things, they have to implement. So, they were somewhere reluctant about it. But then, first, we try to make the post do it. So, that worked.*

Based on the focus group data, the fifth hypothesis developed was

> *H5: Industry 4.0 requires inducting a process champion*

4.1.6 H6 Training Efforts

Digital transformation is argued to need time to percolate, requiring reinforcing training efforts. In this regard, the expert three notes as follows,

> *the training activities have to be managed in such a way so that the people get time to get themselves accommodated within the framework*

The training activities might also result in new skills being added to the project teams so that they would understand and actively use the new technological interventions. Based on the focus group data, the sixth hypothesis developed was

> *H6: Industry 4.0 requires training efforts*

4.2 People related implementation

The data unveiled three prominent issues in the people dimension - benefit project and empathising with the teams, stakeholder integration, and influencing the total team climate.

4.2.1 H7 Benefit projection and empathy

Experts agreed that project workers should be made aware of the benefits of industry 4.0 – both within projects (execution) and outside of the project. Besides, the implementation team would need to handle the change in a soft and more empathising manner with the implementation teams.

In this regard, expert one notes as

> *[…] many times, what happens is we are just implementing a part of the technology, and the benefit may not directly give benefit the people. The implementation may not give a benefit. The people at the project level, hence there is a lot of resistance.*

Furthermore, expert one further added emphasises a tangible benefit to the project teams.

> *Let's say, for example, quantities. Now, if the quantities are generated, and if the quantities are only going to help you for a broad-level estimation and not help you for, let's say, client billing or subcontractor billing. So, in the end, the benefit of BIM for the guy at the project site is not there. He would end up saying, OK, this is all good. I'm getting quantities. But can I replace this? Or can I use this quantity directly for billings? Can I use these quantities directly for subcontractor billing? And probably the answer is NO., and that's where the entire intent and interest of the team implementing any change goes away […]*

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Expert three also reflected upon his experience and spoke

> *So, whenever we change, I initially found there is resistance, but once they found that these results are definitely helping them, they become part and parcel.*

It is recommended that projecting the benefits to the project stakeholders can be done by showcasing successes, demonstrating small examples, and conveying the importance of the change in the digital transformation journey. This would allow people to learn the usefulness and appreciate the worthiness of the adoption.

Empathising is needed while handling the people subjected to change in addition to the top-down approach and mandates. Expert three reflected it as

> *People must be really softly handled… their aspirations and basic problems must be addressed, and they have to be shown what they are doing. But there should be done strategically.*

Based on the focus group data, the seventh hypothesis developed was

> *H7: Industry 4.0 needs to project benefits with empathy to the project team*

4.2.2 H8 Stakeholder integration

Experts suggest that incorporating industry 4.0 would mean internal and external collaboration where the typical stakeholders of a construction project would need to be integrated. This integration needs to be seamless and effective for their performance. Expert one highlighted his experience as

> *…e.g., when we speak of blockchain as a technology in construction, we should not restrict it to a stakeholder, which can be either client, which can be either a contractor or a subcontractor or a vendor. If we aim to leverage the technology of blockchain, when we're talking of a complete life cycle management and look at it as not stakeholders but as a product which is a facility which is being built, that's when the benefit of blockchain in comes into for all stakeholders.*
>
> *We did a pilot on the blockchain. Considering some of our vendors' little forward thinking and when we looked at the life cycle from a contract management perspective, we were looking at the contract from client to SP, SP to its vendor. And they ran a complete life cycle of billing, certification, and off-payment. Part of this exercise was on people, where we saw a lot of benefit in not repeating the task because when we speak of billing and certification, there are so many stakeholders involved, and the same task is being performed multiple times by people.*

The experts suggested that only with such integration could one leverage all the benefits of these technologies. It is suggested that internal collaboration needs to be switched from being the bureaucratic line of command to a democratic way of working wherein sharing of information becomes pivotal. It was further mooted that the long strategy must encompass holistically to get greater and synergic benefits to the project delivery. Expert three notes as,

> *[…] each technology will be giving relatively small impact to each but this whole together, it's going to make a revolutionary change into the way traditional practices are being done and uplifting in a totally different level altogether.*

Based on the focus group data, the eighth hypothesis developed was

> *H8: Industry 4.0 needs to integrate all stakeholders*

4.2.3 H9 Influencing total team climate

The experts also pointed out that the implementation climate is essential. The changes required in the implementation climate pertain to the soft aspects of the project staff stemming from the readjustment of power. In this regard, expert four noted,

> *[…] require some emotional and social aspects to be taken care of. A guy leading an earlier meeting needs to take a side step because this new guy with a new skill set comes to the interviews now. Many implementations fail due to non-compliance or lack of support from other peers.*

Thus, it is asserted that such changes would help staff acclimatise to the internal or external changes brought by digital technologies. Based on the focus group data, the ninth hypothesis developed was

> *H9: Industry 4.0 needs to influence total team climate*

4.3 Process related implementation

4.3.1 H10 Process re-engineering

Highlighting some of the mistakes or pitfalls that cause poor adoption of digitalisation success is that often old processes are added to new processes. Thus, in the context of process-related strategies, experts have mooted that digitalisation strongly requires process re-engineering, wherein old reductant processes should be removed to make space for the new processes that align with the digitalisation strategy. In this regard, expert one notes as follows:

> *Suppose the new process is not superseding the existing process. So, many times what happens is you want a new process also and the underlying old process as well and hence. The project team would not see much benefit in implementing it now.*

The adoption of industry 4.0 is also argued to cause disturbance in the existing systems. Furthermore, the team's resistance also demands process re-engineering wherein expert five shared the experience within his organisation after a pilot of digitalisation as:

> *[…] the people are so busy with the other activities that they think this is something like an overburden to them and will not impact there.*

Similarly, expert four mooted the importance of process re-engineering in pursuing digitalisation in the construction industry as

> *… the process must be a paradigm shift … regards the process when we are talking about digitalisation being predominantly the process, not the technology. Of course, the technologies are the tools, as is a pen to write a story.*

Based on the focus group data, the tenth hypothesis developed was

> *H10: Industry 4.0 needs to re-engineer the processes*

4.3.2 H11 Customising the requirements

While process re-engineering is at a level of routines and activities of the project staff, experts also highlighted that there is a need to customise the technological solutions to meet the current organisational culture and functioning. In this regard, expert two noted

> *…one submission is that we found that if this relationship is the part of the system, whatever we implement, any system. If it is a part of the system, then and then only it is successful. If it is not a part of the system, then if you prepare any good software or any goods application and if it is not. …we never found any technology we could use directly. There is very little quantity of such technologies, so customisation of this technology as far as the organisation's requirement is most important...*

The data also unveiled the need for a product champion in customising the requirements. In this regard, expert two continued to note

> *… the role played by this person is the most important, and the entire success depends upon this person only because whatever the technology, ultimately, the changes are done by, not by, the civil engineer. Several engineers from some software agencies or some software consultancy. So, we must be able to inform our requirements to them properly.*

Based on the focus group data, the eleventh hypothesis developed was

> *H11: Industry 4.0 depends on customising the requirements of industry 4.0 to organisation or project*

4.4 Data related implementation

4.4.1 H12 Real-time data-driven problem diagnostics

The focus group data revealed a need to utilise data to allow data-driven predictive analytics owing to the surge of projects in the construction sector, both in terms of the number of projects and the cost of such projects. In this regard, expert one noted,

> *What we are really getting into is getting granular information. Earlier that granular information was processed by individuals since the number was manageable by one individual, and the information is to stay in mind and with their intellect used to process the information and project or projects.*

This has led to two challenges. They are articulated as a lack of proper documentation (particularly in government organisations) or a lack of real-time data. The conventional practice, which is currently in the drafting tools, needs to embark on the journey through engineering tools. This is suggested as a requirement to adopt industry 4.0 technologies. It is also argued that the data for industry 4.0 must possess the characteristics such as real-time, seamless, and visibility of data to everyone, each at a higher level than the previous, facilitating towards effective prognosis, as noted by expert one as

> *Do we have that kind of transparency in data in the information available where we can really look at why the delay is rather than who has caused the delay?*

Based on the focus group data, the twelfth hypothesis developed was

> *H12: Industry 4.0 needs to have real-time data-driven problem diagnostics*

4.4.2 H13 Federated data

Adding that, industry 4.0 addresses the issue of causes of delays. For instance, expert 3 highlighted the power of real-time availability of information that needs to be federated across all phases of the project and all stakeholders. He notes it as

> *[…] any time it [information] can be dug, and it should be available for deciding out of the information which should be made available, and that should be seamless. The golden thread needs to be carried from the conception and conceptualisation to the delivery to the operation and maintenance and to really giving value to the users, and that is what the seamless connection is impossible to make through digitalisation, and this is going to change.*
>
> *[…] all these systems (referring to structural, architectural, plumbing, sanitary, HVAC etc.) must be collaborative, federated, and measured. […] if it is seamless […] taking together to the asset management level, that means the entire asset lifecycle management*

Thus, experts (e.g., 2 & 3) emphasised the seamless availability and transfer of federated data as crucial precursors for industry 4.0 technology implementation in the construction industry.

Based on the focus group data, the thirteenth hypothesis developed was

> *H13: Industry 4.0 needs to have federated data*

5. TESTING THE HYPOTHESES THAT EMERGED FROM THE FOCUS GROUP

This section presents the results of testing the hypotheses emanated from the focus group through the questionnaire survey. Table 4 shows the statistical analysis using SPSS 23 version. The Cronbach's Alpha (α) is calculated as 0.91, indicating high data reliability (Hair et al., 2018).

Table 4: Statistical Analysis of the Industry 4.0 intervention hypothesis for the Indian construction industry

No.	**Hypothesis**	**RII Rank**	**PM Certification* (n=63)**		**Size of Organisation[&] (n=63)**		**Trade[&] (n=63)**		**Stakeholder[&] (n=63)**	
			S/NS?	**Sig.**	**S/NS?**	**Sig.**	**S/NS?**	**Sig.**	**S/NS?**	**Sig.**
H1	By having a long-drawn digitalisation strategy	6	***S***	0.238	***S***	0.085	***S***		***S***	
H2	Using mandates and a top-down approach	12	***NS***	0.276	***NS***	0.566	***S***		***S***	
H3	Through technology, scout teams and external collaborations	8	***S***	0.646	***S***	0.786	***S***		***S***	
H4	Developing cross-functional teams	3	***S***	0.214	***S***	0.366	***S***		***S***	
H5	Inducting a process champion	7	***S***	0.439	S	0.968	***S***		***S***	
H6	By training efforts	1	***S***	0.757	***S***	0.179	***S***		***S***	
H7	By projecting benefits with empathy to the project team	8	***NS***	0.022	***S***	0.812	***S***		***S***	
H8	By integrating all stakeholders	2	***S***	0.698	***NS***	0.004	***S***		***S***	
H9	By Influencing the total team climate	10	***NS***	0.000	***NS***	0.025	***S***		***S***	
H10	By re-engineering the processes	11	***S***	0.12	***S***	0.311	***S***		***S***	
H11	By customising the requirements of industry 4.0 to organisation or project	4	***S***	0.512	***S***	0.222	***S***		***S***	
H12	By having real-time data-driven problem diagnostics	5	***S***	0.486	***NS***	0.007	***S***		***S***	
H13	By insisting on federated data	13	***S***	0.177	***S***	0.276	***S***		***S***	

Note: Asymptotic significances are displayed. The significance level is 0.05; S - Significant at 95% confidence interval at *p*-value =0.05.; NS – Not significant and hence the null hypothesis that distribution of the hypothesis is same across the grouping of respondents in rejected; * Mann-Whitney U (MWU) Test; [&] Kruskal-Wallis (KW)Test.

5.1 Ranking of Industry 4.0 interventions and differences in groups

Relative importance index (RII) based ranking showed that respondents emphasised the need for stakeholder integration (H8) (rank 1) to allow industry 4.0 in the construction industry. The results confirm that increasing importance is placed on the need for training activities. They emphasised the need for training efforts (H6) (rank 2) to enable the implementation of industry 4.0 in the construction industry. Developing cross-functional teams (H4) ranked 3rd among the proposed interventions. Similarly, the experts meant that implementing industry 4.0 in construction would also require customising the requirements of industry 4.0 to an organisation or the project (H11) (rank 4), making the concept of construction 4.0 more specific in its application. The fifth-ranked intervention is to have real-time data-driven problem diagnostics (H12). Yet, surprisingly, the overall responses put the need to generate federated data (H8) in the last (rank 13). Without federated data, industry 4.0 will not help harness the complete potential. For instance, real-time data-driven problem diagnostics would require data inaccessible and analysable form of the whole system, which demands federated data generation.

5.2 Effects of PM certifications on Industry 4.0 perceptions

Mann-Whitney test results are greater than *the p*-value (0.05) at a 95% confidence interval showing no statistically significant difference in the perception of various groups among the sample groups, and therefore null hypothesis is retained (Table 4). However, the perception differed between respondents with some project management certifications from others without any PM certification on the interventions, namely, benefit projection to the employees and empathising with them in the change process (H2). The second rejected hypothesis in this Mann-Whitney U (MWU) test is that respondents differed on whether industry 4.0 required influencing the total team climate. This indicates that the level of awareness due to project management certifications has played a role in softer practical aspects of project management theory. For instance, rejecting the hypothesis on influencing total team climate (H4) means that respondents disagreed on the essentiality of a holistic approach instead of adopting a piecemeal approach. This concurs with the focus group findings that these softer practical aspects and the piecemeal as the prevailing status quo in the industry.

5.3 Effects of Size on Industry 4.0 perceptions

When the organisational size is considered a grouping variable, three hypotheses were rejected between groups according to the KW test. They are stakeholder integration, influencing total team climate, and real-time data-driven problem diagnostics. This disagreement implies that the organisation's size, which in turn dictates the value of the project getting executed, influences the number of stakeholders and project participants. Accordingly, the hypotheses concerning integrating the project stakeholders and influencing the project team climate are perceived as not relevant to industry 4.0 integration in the construction industry. This also adds to the insight that in smaller projects possibly executed by smaller firms, real-time data-driven problem diagnostics becomes an effort that yields fewer results or could even become irrelevant. This verifies the prevailing context that SMEs still operate with non-interoperable and non-intelligent project data (Makabate et al., 2021). More particularly, the usage of field records, allied data transfer during operations, and the physical exchange of data among the team members, even though multidisciplinary, prevail in SMEs of the construction industry (Makabate et al., 2021).

5.4 Effects of Trade group and Stakeholder group on Industry 4.0 perceptions

There are no differences in the perceptions based on the respondent's trade or the stakeholder group, according to the KW test. This indicates that the developed hypotheses are valid across the trades and stakeholder groups. This confirms that industry 4.0 implementation is equivocally conceptualised as the same across the public sector, private sector, governmental bodies and also between various trades that form part of the construction project (Eccles, 1981), though implementation or adoption levels and perceptions differ.

Thus, while trade and stakeholder groups are united in the relevance and adaptability of the developing digitalisation strategies developed from the focus group, PM certifications and the organisation's size have differing influences. PM certifications influence caused variation in the perception that digitalisation of the construction industry can be achieved by having real-time data-driven problem diagnostics (H7) and by using mandates and a top-down approach (H9). Similarly, the size of the organisation caused a difference in perception that digitalisation of the construction industry can be achieved by insisting on federated data (H8), by using mandates and a top-down approach (H9), and by inducting a process champion (H12).

6. FRAMING PERSPECTIVE OF THE STRATEGIES

The focussed group data indicate that the changes in the practices can be viewed from at least four perception frames, namely redundancy, accommodation, amplification, and introduction. The mapping is shown in FIG. *4*.

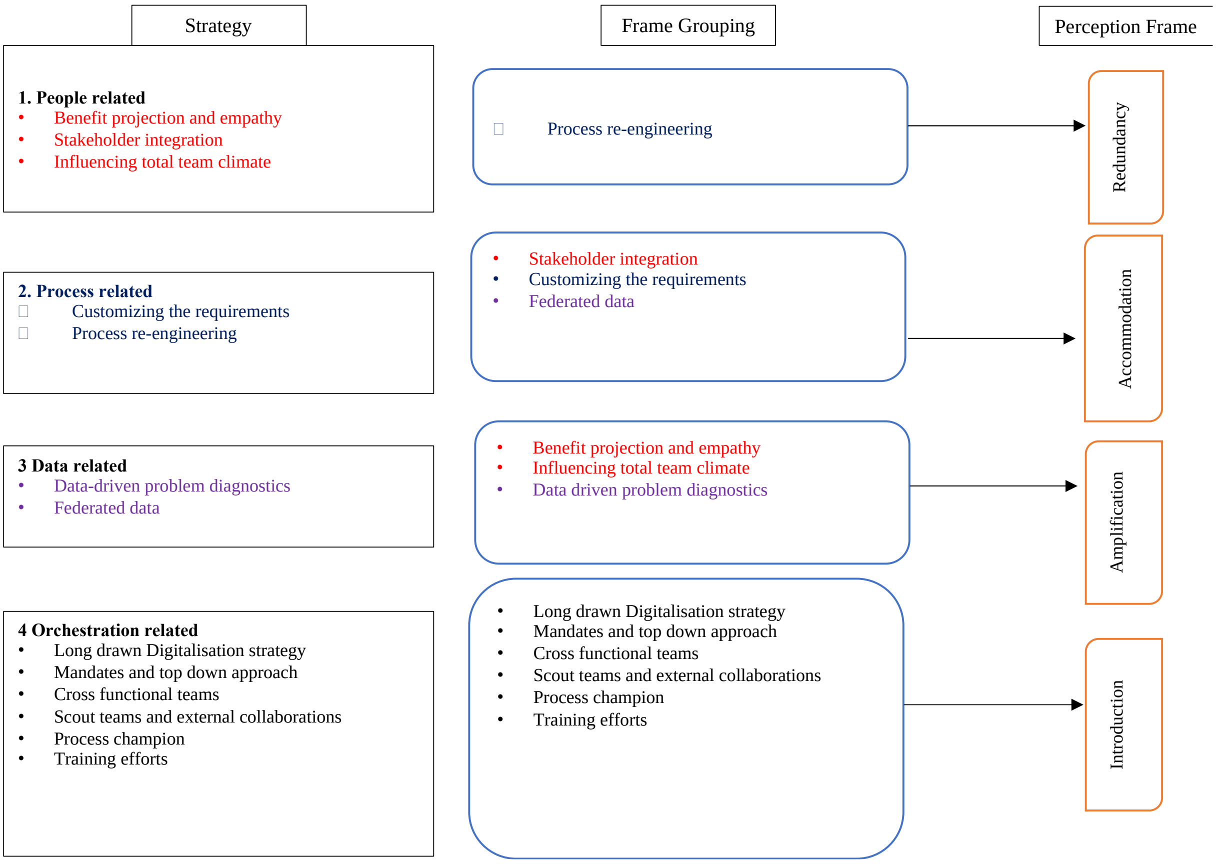

FIG. 4: Framing theory interpretation of construction 4.0 hypotheses

According to our qualitative and quantitative data, the invocation of industry 4.0 in the construction industry would mean firstly that old processes need to be removed. Thus, experts seem to indicate the implementation strategy with a redundancy frame. In this regard, the old processes incompatible with industry 4.0 technologies and practices must be removed.

Secondly, while the active involvement of various parties is long advocated, it was partial and sometimes limited to only a few key stakeholders. According to our data, industry 4.0 demands complete and total integration of all project stakeholders- thus establishing the accommodation frame. Additionally, after deleting the redundant processes, adding the requirements, or customising the requirements of industry 4.0 to suit the projects, generating federated data can be viewed from the accommodation frame. New processes lead to new rules and roles that can orchestrate digitalisation.

Thirdly, one of the core arguments raised in our qualitative data is that project teams, particularly the front-line management, are often deprived of benefiting from the adopted industry 4.0 technologies. They are sometimes unaware of their benefits. Thus, amplification needs to be done by projecting the benefits to the project team and empathising with them when they manage the change. Additionally, while some form of data is generated even before industry 4.0, the plethora of data generated from the constellation of tools and technologies of industry 4.0 would lead to many folds amplification of the data, which would facilitate diagnostics and analytics to support decision-making. This also forms part of the amplification frame as perceived by the focus group experts.

Fourthly, the whole discussion around industry 4.0 is about introducing a digitalisation or industry 4.0 strategy necessarily is about having a long-term strategic plan. Other necessary strategies that are perceived from the introduction frame are that mandates are introduced predominantly from top management, cross-functional teams

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are introduced as opposed to other conventional forms of team structuring, scout teams that search for new technologies and new collaboration that can potentially be harnessed are introduced, and special training efforts are introduced along with the introduction of a process champion who can take the strategy forward. So, the framing perspective of long drawn strategy is a new addition (frame 4), mainly due to digitalisation in projects without which, the respondents argue, digitalisation will not see the potential benefits. Currently, the perspective of strategy in the construction project organisation is for the level of executing the projects.

Surprisingly, issues concerning the ethics of AI and data usage were not raised (Wirtz et al., 2018). Perhaps the answer lies in the maturity of the construction industry, where the availability of usable data itself is the immediate need/challenge in this sector. This is consistent with extant literature stating that implementing industry 4.0 technologies would also demand pursuing and improving project management principles (Rosin et al., 2020).

Consistent with past findings (Silvestri et al., 2020), we reinforce that future project management revolves around value capturing within projects with the interlinkage of technologies and humans. In particular, as seen in our data, industry 4.0's success is argued to be dependent on the technological processes' acceptance, change, and interactions between the constellation of actors and the strategies that govern them.

7. DISCUSSION AND CONCLUSIONS

Digital transformation or digitalisation often involves using technological innovations in the form of advanced tools throughout the project life cycle. The industry has transformed from the earlier notion that project success is agnostic to the tools adopted compared to project planning based on project management processes (Dvir et al., 2003). Increasingly, a strong interplay is witnessed between management processes and technology adoption (Kane et al., 2015). This is especially true of the influence of such tools on the project stakeholders and related processes wherein strategy supersedes all other aspects, including technology (Kane et al., 2015).

In this study, we started by exploring the influence of industry 4.0 on the principles and practices of project management. Construction 4.0 and the digital transformation agenda require a road map for implementation, and this study addressed this gap.

To this end, a three-pronged research framework is employed. First, a focus group is conducted with experts from the Indian construction industry. This yielded 13 hypotheses that address how construction 4.0 can be integrated into the construction industry. These 13 hypotheses are then validated using a questionnaire survey with a broader audience. The validation is done by checking whether any differences exist between experts who have any project management certifications, the size of the organisation, and the sector's trade group or stakeholder group. Here, PM certification has been taken as a measure of the knowledge and skill of the respondent.

The findings primarily indicate that while project management principles remain the same, project management practices are argued to change. In particular, the data analysis unveiled a framework comprising 13 strategy-related hypotheses for adopting industry 4.0 in the construction industry. The qualitative data also provided the necessary depth to establish the causal links between various strategies, which are converted into a causal loop diagram. Stakeholder integration, process re-engineering, training activities, and the need to generate federated data emerged as the top four crucial strategic interventions in terms of PM practices. When the size is considered, the importance of strategies such as stakeholder integration, influencing total team climate, and real-time data-driven problem diagnostics are perceived differently to different organisational sizes, there is an agreement of relevance of the identified strategies across trades and stakeholder groups.

Implementation of industry 4.0 in the construction industry must embark on a change in a coordinated manner with strategies, top management initiatives and collaborations to know the kind of changes required. Consistent with the extent of literature (Criado-Perez et al., 2022), as the construction industry fails to adopt an orchestrated and common approach to digital technology, impeding effective collaboration, long drawn digitalisation strategy is the key. One such important aspect is having cross-functional teams, which eliminate the old processes of independent working styles. The staff also would need the training to enable the upskilling in keeping with the industry 4.0 requirements. The construction industry would also need to consider the highly fragmented stakeholder groups.

Findings would help academicians to carry out research that refines the project management principles, and it would also help practitioners to make process changes in their organisations while delivering their projects through industry 4.0. This study would provide more clarity in dealing with the complex management challenges and the influences prevailing in the construction industry. However, owing to the limitations such as one focus group, Indian context, and testing through perception based survey instrument, future studies can focus on case studies to gain deeper understanding on the change process through methodology such as action research or by studies longitudinally.

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